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Indiana Value-Added Program

Improving Moisture Retention of Microwave Popcorn Using Edible Coating for Better Shelf-life and Popping Performance

Bruce R. Hamaker, Ph.D.
Professor of Cereal Chemistry, Department of Food Science
Purdue University, West Lafayette

Summary

In our value-added research project, lipid-based coatings (particularly Acetem - an approved acetic acid ester of monoglycerides from fully hydrogenated palm oil) were clearly shown to improve popping performance (lower number of unpopped kernels and larger flakes) of popcorn hybrids differing in microwave popping quality. The coating improved the ability of popcorn kernels to retain moisture content over their uncoated counterparts during microwave heating and extended storage. Moreover, the coating improved popping performance of poor performing hybrids indicating that it can be used to minimize problems associated with marginal hybrids or poor crop years. Other coatings tested – protein and carbohydrate-based - resulted in higher moisture loss presumably due to a "wicking" out of moisture from the popcorn kernel. Collaborative studies with Ag Alumni Seeds on varietal differences in popping performance and resistance to moisture loss with storage and microwave heating showed dramatic results. Popcorn varieties with high number of unpopped kernels lost moisture faster than those with low unpopped kernels. This indicated that number of unpopped kernels is related to moisture loss. We also conclusively found that Acetem coated popcorn kernels lost moisture in a much lower rate than their uncoated counterparts during microwave heating. This low rate of moisture loss was strongly correlated with improved popping performance. We plan to conduct further studies to understand the inherent factors responsible for moisture loss will be conducted. This report includes additional data on the starch amylopectin molecular weight of four popcorn hybrids. Our data showed differences in amylopectin molecular weight among hybrids. We are currently studying the potential effect of starch structure on popped corn texture.

Overall, this study showed that lipid-based coatings can be used to improve microwave popcorn performance by decreasing unpopped kernels and increasing popping volume. Coatings could further be used to extend storability of microwave popcorn, particularly for export markets, and to improve and equalize popcorn performance of varieties.

Objectives

1. To determine the effectiveness of microwave popcorn coatings on retaining moisture during microwave heating and extended storage.

2. To select the best edible coatings that give maximum popcorn volume and minimal waste (% unpopped kernels) in microwave popping.

3. To determine the effectiveness of lipid-based coating on improving popping performance among hybrids with varying popping performance.

4. To investigate relationship between amylopectin fine-structure and final product texture (in progress).

Justification

Consumer popularity of microwave popcorn has steadily increased in recent years, with a significant portion of the US product exported overseas. Two microwave popcorn quality parameters of particular interest to manufacturers and consumers are high expansion volume and the number of unpopped kernels and following microwave popping. These popcorn quality factors are related to kernel properties and to the maintenance of a critical moisture content of about 13.5 to 14%. Loss of moisture from this optimum range lowers popcorn quality by increasing unpopped kernels and decreasing expansion volume. While moisture retention in stored product is not a large problem for the domestic US market, it is a factor in microwave popcorn export markets that require longer product shelf-life. Therefore, improving moisture retention by use of moisture-retaining coatings for greater shelf-life would provide a positive economic benefit for microwave popcorn processors who export their product. Variability in popcorn hybrid performance could also be reduced by use of coatings.

Summary of Previous Project Reports

It widely known among popcorn processors that proper moisture content (about 13.5% to 14% moisture content) is essential for good popping performance. In our previous progress reports for this Indiana Value-Added project, rapid moisture loss during microwave heating, as well as during extended storage, was shown to be detrimental to popcorn popping performance (increased number of unpopped kernels, lower popping and flake volumes). We also showed that coating popcorn with different coating materials gave different popping performance. The lipid-based coating, especially Acetem, was found to be the best coating material to improve popping performance (especially for lowering the amount of unpopped kernels) that was related to a lowering of the rate of moisture loss during microwave heating and storage.

We also showed a diverse popping performance among a range of popcorn genotypes. We found that certain genotypes had poor popping performance and moisture retention ability during microwave heating. The lack of ability to retain moisture during microwave heating correlated well with increased number of unpopped kernels.

We speculated that the lipid-based coating would overcome this inherit problem in some popcorn hybrids. Our research conclusively showed the effectiveness of lipid-based coating for improving moisture retention during microwave heating and extended storage resulting in enhanced popping performance.

We are planning to further investigate inherent factors affecting differences in moisture loss among different hybrids as previously reported. We speculate that cell wall protein and hemicellulose might influence the integrity and pericarp development during growth. Studies reported in literatures indicated that pericarp hydroxyproline rich glycoprotein influenced the pericarp thickness development.

Currently, we are investigating the effect of amylopectin fine structure on final product texture. Our hypothesis is based on studies showing that amylopectin fine-structure influences rheological properties of other cereal-based products. Popcorn hybrids containing a high proportion of long chain amylopectin might produce final products with firm texture. We speculate that it might be due to retrogradation.

Key Overall Results

Accelerated shelf-life study

In our studies, we used a commercial popcorn brand (Orville Redenbacher) and popcorn varieties from Ag Alumni Seeds that were conditioned to 13.5-14% moisture content. We successfully developed a simple accelerated shelf-life system using a desicator filled with saturated sodium bromide and calcium carbonate to equilibrate samples to specific moisture contents (12 and 9%, respectively). Six different coating materials [commercial zein (corn storage protein), Purity Gum (modified food starch), Crystal Tex (dextrin refined from tapioca starch), corn syrup, Acetem (a hydrogenated palm oil product), and crystal gum (specialty tapioca dextrin), food grade paraffin] were tested for their ability to retard moisture loss over a 3 week period. Results showed that the popcorn coated with Acetem showed a significantly lower rate of moisture loss compared to the control (uncoated) and the rest of the coated samples (**Figure 1**). From this observation, it was apparent that lipid-based polymers could be promising coating materials.

Coatings and their effect on popping performance

The objectives of this study were to investigate the effects of different coatings on popping performance. When moisture content was reduced from 14% to 12%, popping volume and number of unpopped kernels were reduced in uncoated popcorn and was markedly improved with the lipid-based coating (Acetem) (**Figures 2 and 3**). Acetem coating resulted in practically no unpopped kernels. Other coatings significantly reduced popping performance, most likely due to a "wicking" of moisture from the kernels. When moisture content was further reduced to 9%, Acetem and paraffin both resulted in improved popping performance (**Figures 4 and 5)**. During microwave heating moisture loss was reduced by the Acetem coating (**Figure 6**). These results suggest a parallel relationship between moisture retention and popping performances over extended period of time, and indicate potential application of using coatings to extend shelf-life of microwave popcorn products.

Varietal differences in moisture loss and popping performance

Some variability in moisture loss during storage of different popcorn varieties was observed (**Figure 7**). We also observed some differences in popping volumes among different varieties under optimum conditions (**Figure 8**). Much more pronounced were differences among varieties in number of unpopped kernels (**Figure 9**). Variety AP 414 had almost no unpopped kernels and had significantly lower moisture loss during microwave heating (**Figure 10**). The relationship between moisture loss and popping performance will be studied in more detail and related to coatings.

Popping performance experiments

At 12% moisture content (below optimum moisture content for popping), a substantial improvement in the amount of unpopped kernels was observed for after lipid-coating of 4 popcorn hybrids (**Figure 11**). Significant improvement (more than 50% reduction in the number of unpopped kernels) was observed that particularly affected poor performing popcorn hybrids (EXP92233 and P618). At 12% moisture content, popping volume of the 4 coated popcorn hybrids was slightly higher than the popping volume of their uncoated counterparts (**Figure 12**). However, only slight improvement in flake size was observed (**Figure 13**).

As moisture content was further decreased to 9%, overall popping performance (number of unpopped kernels, popping volume, and flake size) decreased. Significant improvement in the amount of unpopped kernels was observed after lipid-coating popcorn compared with their uncoated counterparts (**Figure 14**). At this moisture content, improvement in popping volume was also observed with coating (**Figure 15**), and overall improvement in flake size, although minimal, was observed due to coating (**Figure 16**).

A correct amount of moisture is essential for good popping performance. Moisture is essential to develop superheated pressure inside the popcorn kernels prior explosion. The ability to retain moisture during microwave heating logically would be essential for good popping performance. We showed that moisture retention ability of different popcorn genotypes was improved by the lipid-based coating. Lipid-based coating of popcorn hybrids resulted, in every case, in superior moisture retention compared to their uncoated counterparts (**Figure 17**). This result correlated very well with the above popping performance experiments, where popping performance was increased significantly with lipid-based coating, and, thus, shows that the coating aids in retention of moisture during popcorn heating causing markedly improved microwave popcorn performance.

Our initial step to investigate the effect of amylopectin fine structure was to determine the molecular weight of amylopectin from four different popcorn hybrids used in previous experiments. We used a size exclusion chromatography – refractive index - multi angle laser light scattering equipment to determine amylopectin molecular weight. Our analysis showed differences in amylopectin molecular weight (**Table 1**). We will further debranched the amylopectin to determine different proportions of amylopectin chain length.

Conclusions

The microwave popcorn coating study showed conclusively that certain lipid(fat)-based popcorn coatings dramatically improved popping performance, most notably in decreasing the number of unpopped kernels in a microwave bag. Unpopped kernels are generally recognized to be the biggest negative consumer factor for microwave popcorn. We calculate that the coating material alone would add about 3 cents/microwave bag in cost. Our results indicate that coating popcorn could not only improve microwave popcorn quality, but could have a significant effect of increasing storability (shelf-life) of popcorn for the export market. Currently, exported microwave popcorn has a limited shelf-life due to moisture loss resulting in reduction in quality. Lastly, our results show that coating of microwave popcorn would improve performance of poorer quality varieties. This could be of particular importance in years where popcorn quality varies.

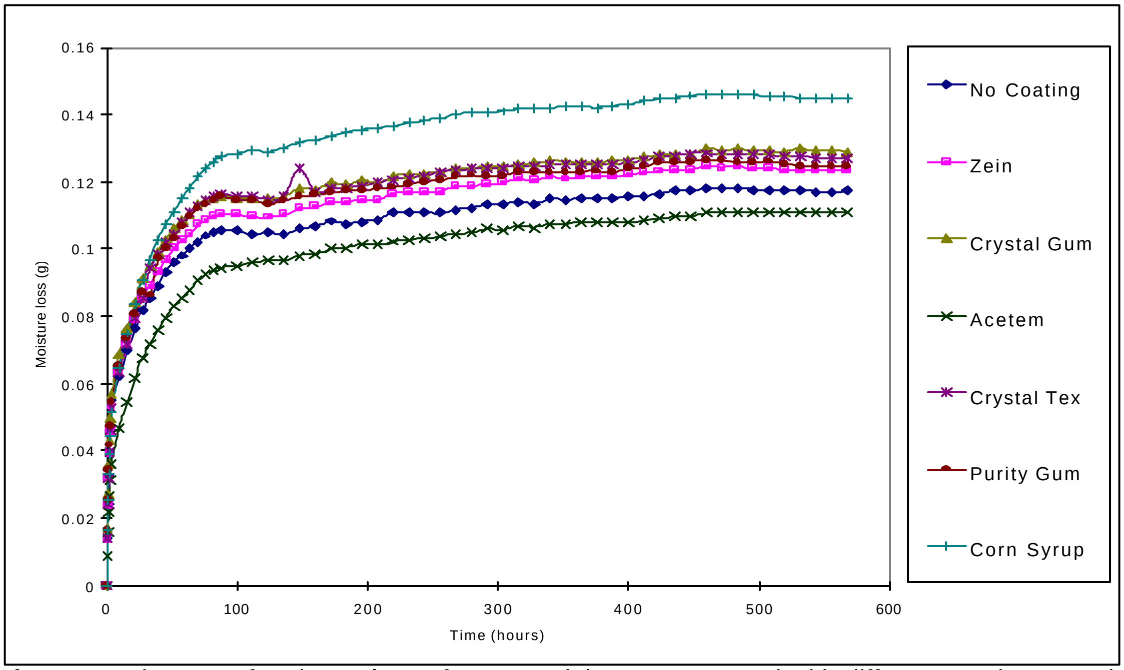

Figure 1. The rate of moisture loss of commercial popcorn coated with different coating materials over the period of approximately 3 weeks using an accelerated shelf-life system with saturated sodium bromide solution.

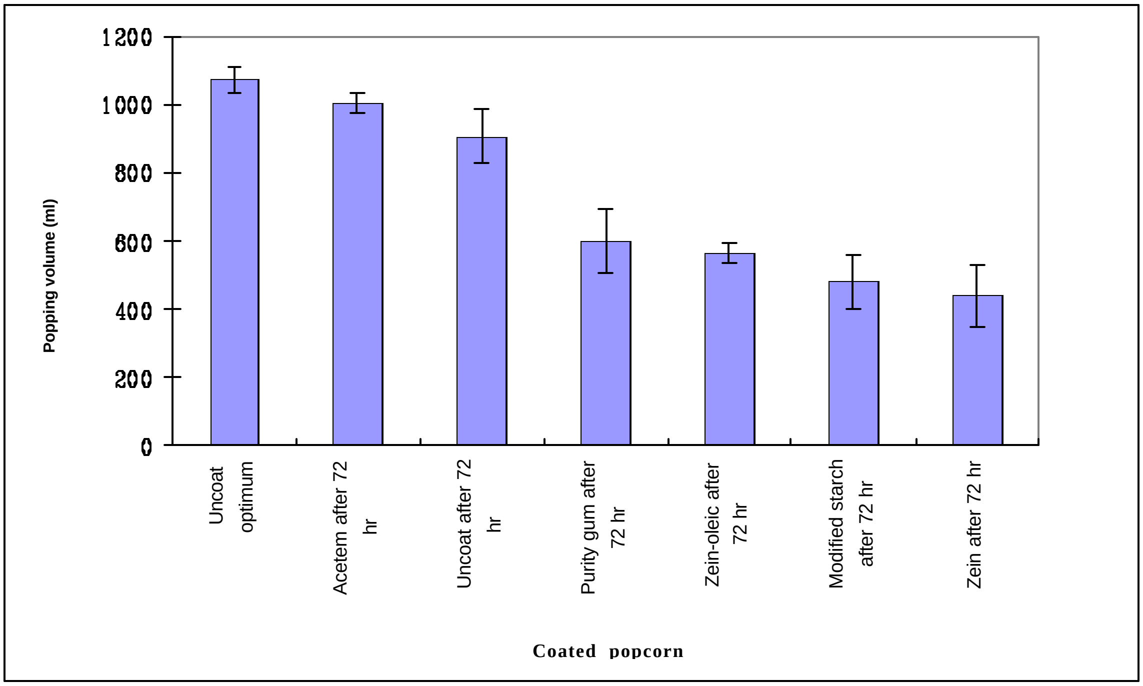

Figure 2. The popping volume of commercial popcorn coated with different coating materials. The moisture content of samples was reduced (72 hours) to 12% prior to popping experiments.

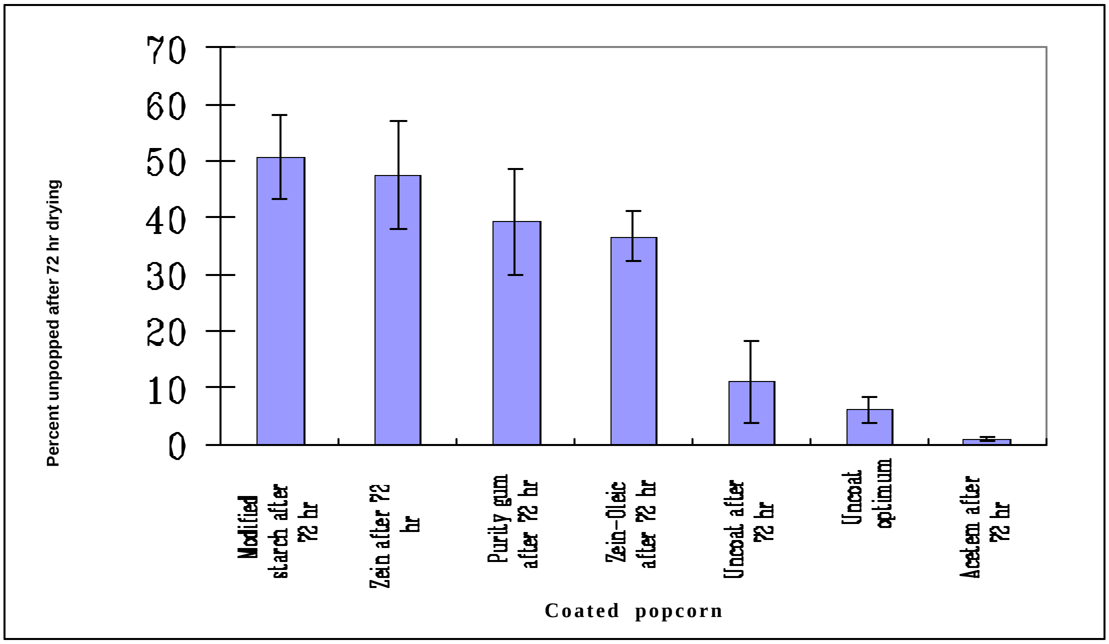

Figure 3. The percent of unpopped kernels of commercial popcorn coated with different coating materials. The moisture content of samples was reduced (72 hours of drying) prior to popping experiments.

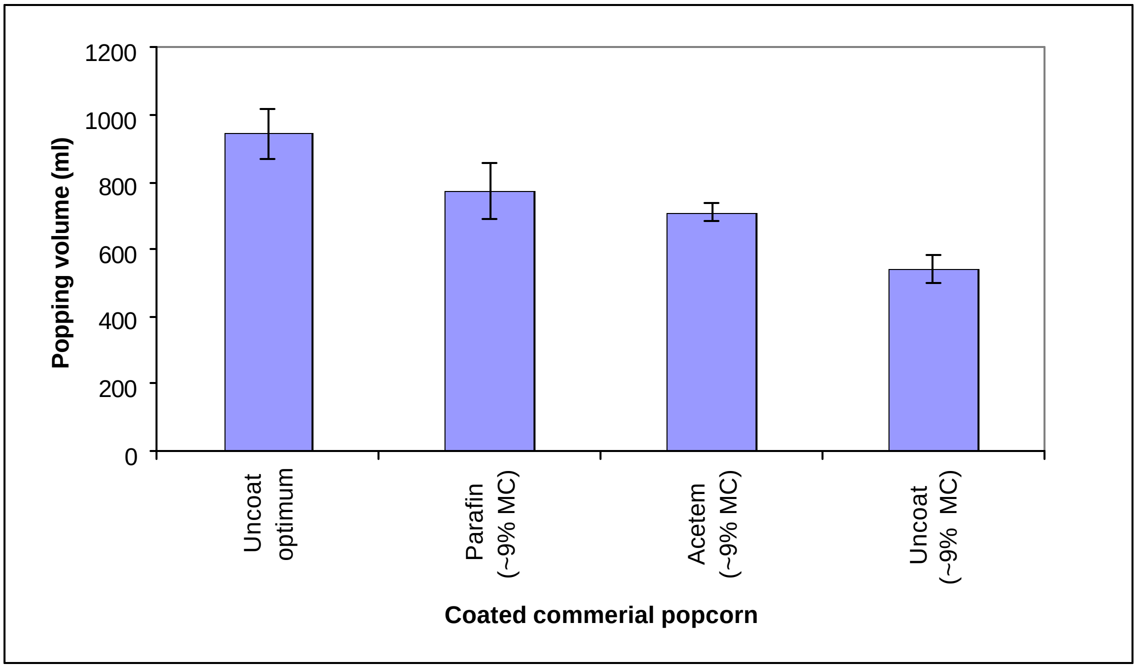

Figure 4. The popping volume of commercial popcorn coated with paraffin or Acetem, both lipid-based coating materials. The moisture content of samples was reduced (48 hours) to 9% prior to popping experiments.

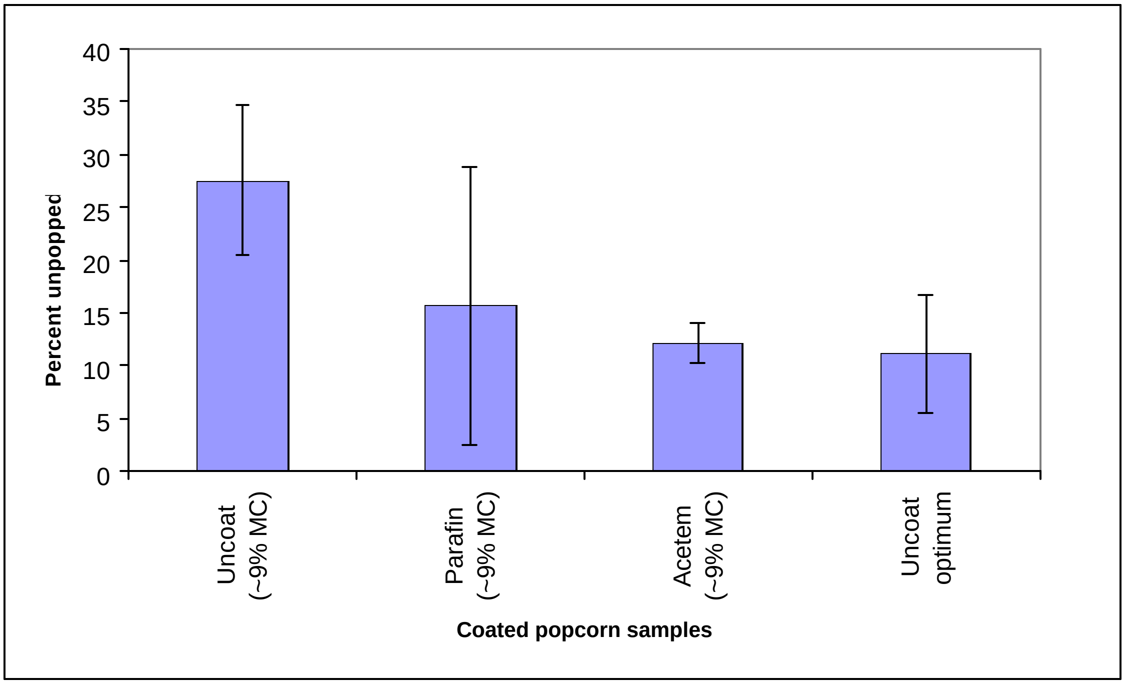

Figure 5. The percent of unpopped kernels of commercial popcorn coated with paraffin or Acetem, both lipid-based coating materials. The moisture content of samples was reduced (48 hours of drying) to 9% prior to popping experiments.

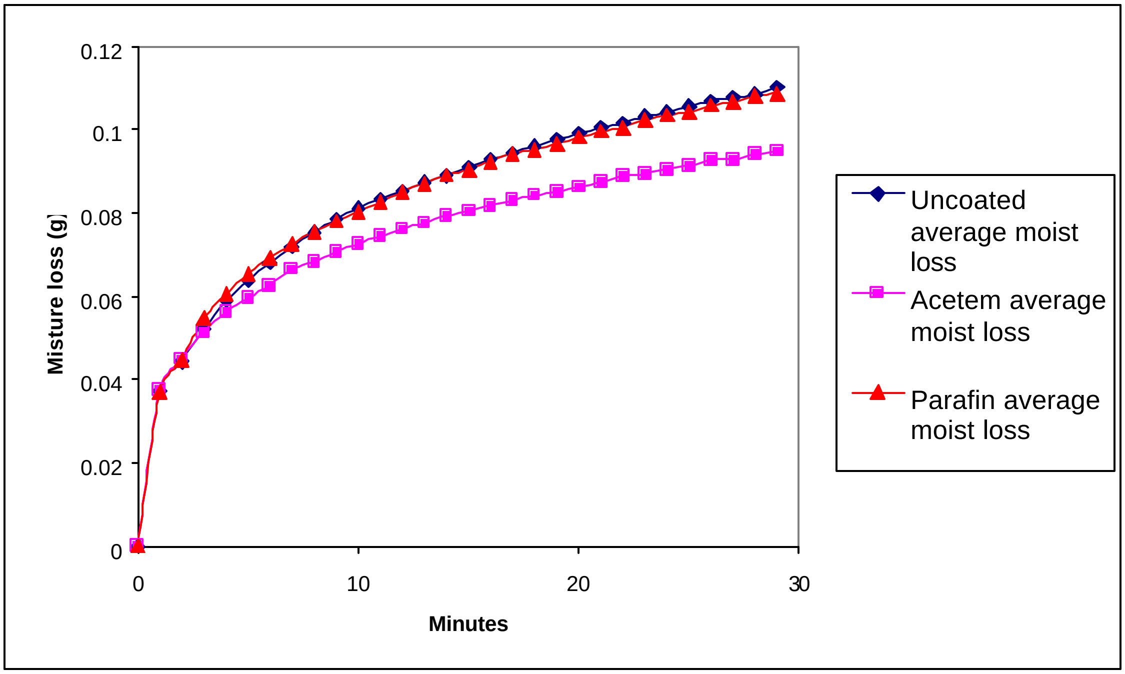

Figure 6. Moisture loss during microwave heating of commercial popcorn uncoated and coated with Acetem and paraffin.

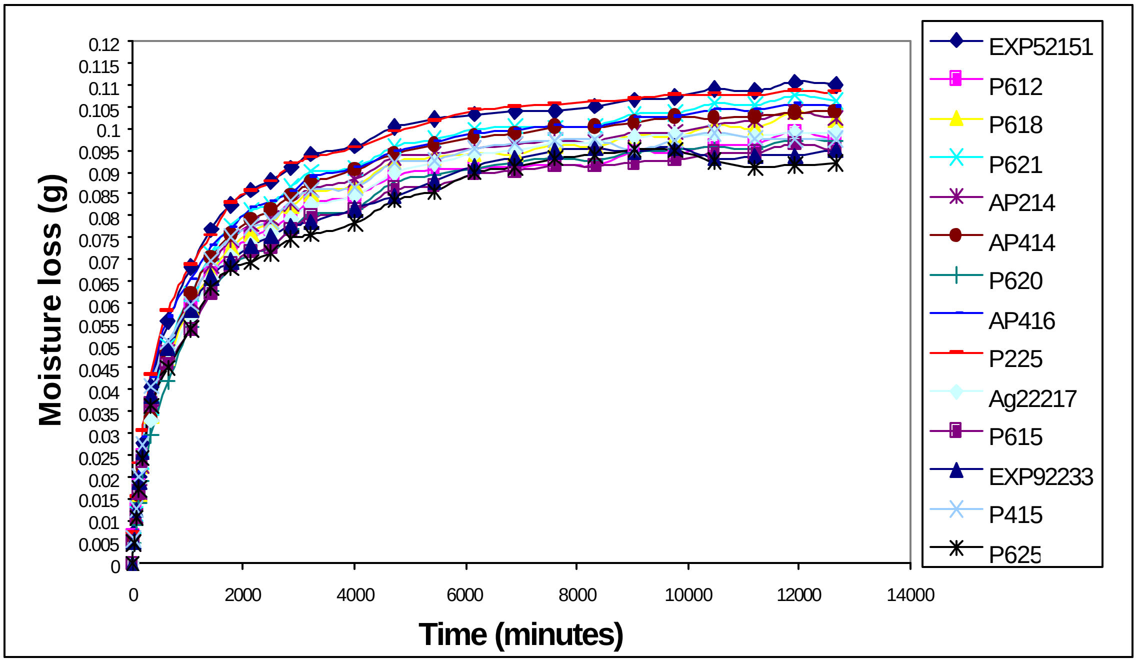

Figure 7. The rate of moisture loss of fourteen different popcorn varieties over a period of one week.

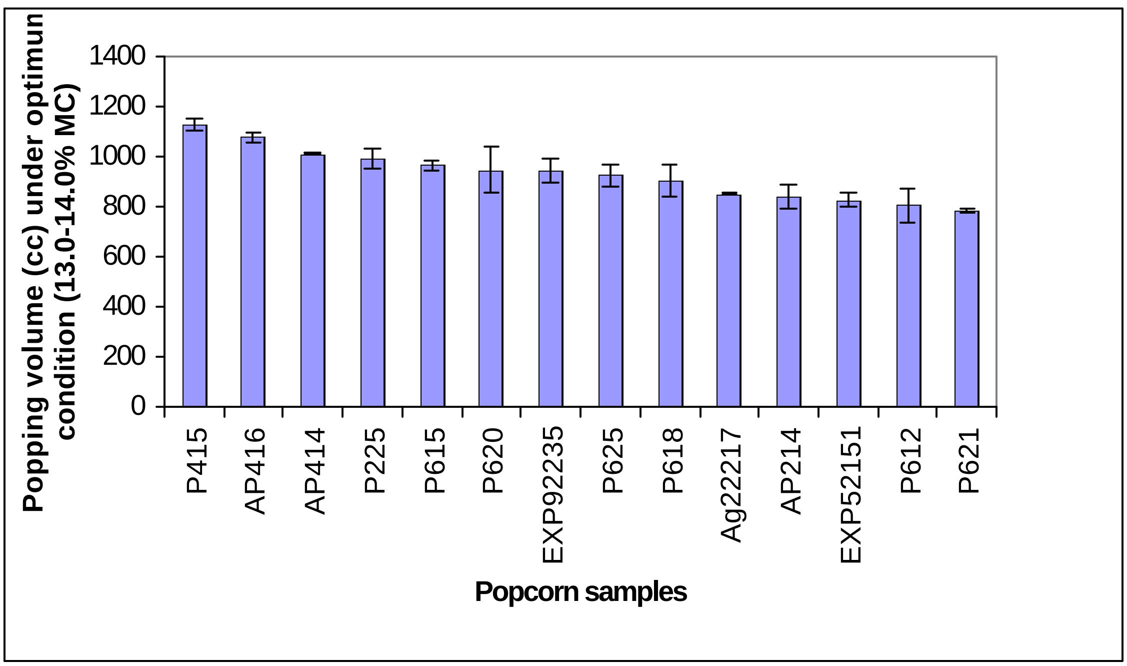

Figure 8. The popping volume of fourteen different popcorn cultivars under optimum conditions (13-14% moisture content).

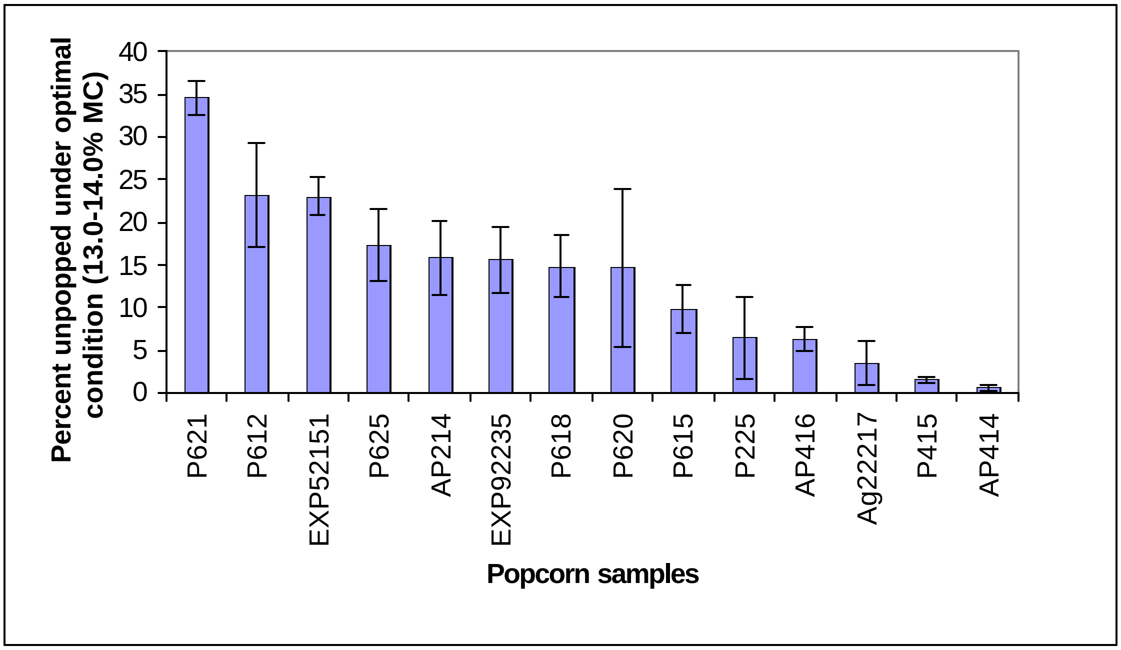

Figure 9. The percent of unpopped kernels of fourteen different popcorn cultivars under optimum condition (13-14% moisture content).

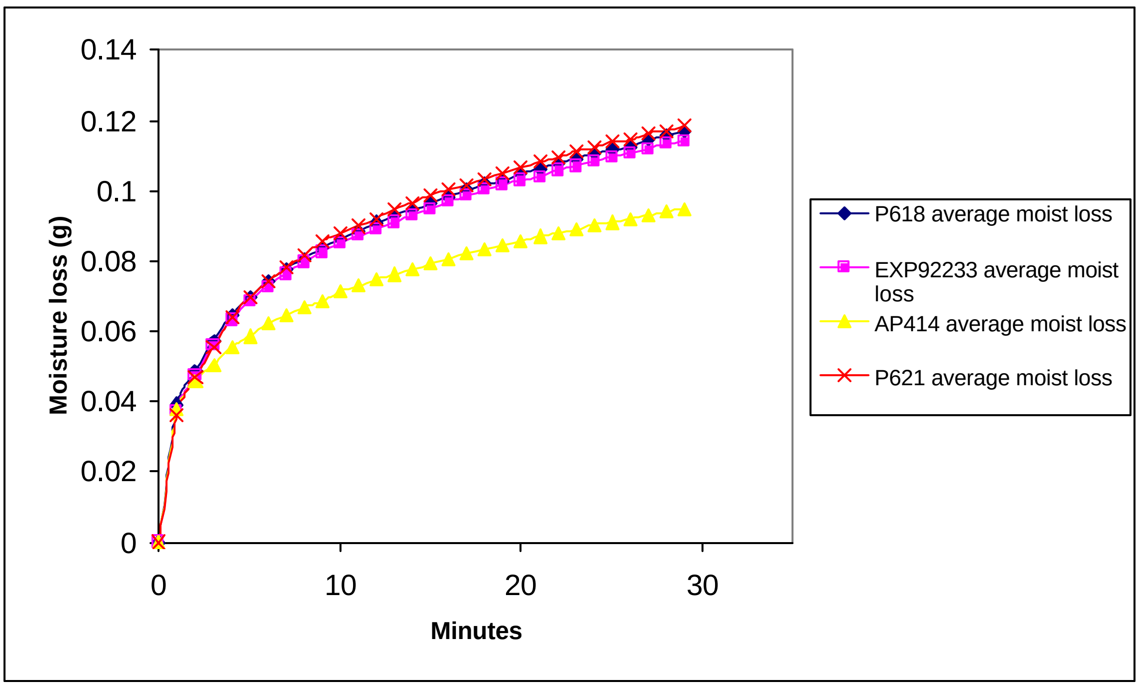

Figure 10. The average moisture loss of four different cultivars during microwave oven cooking.

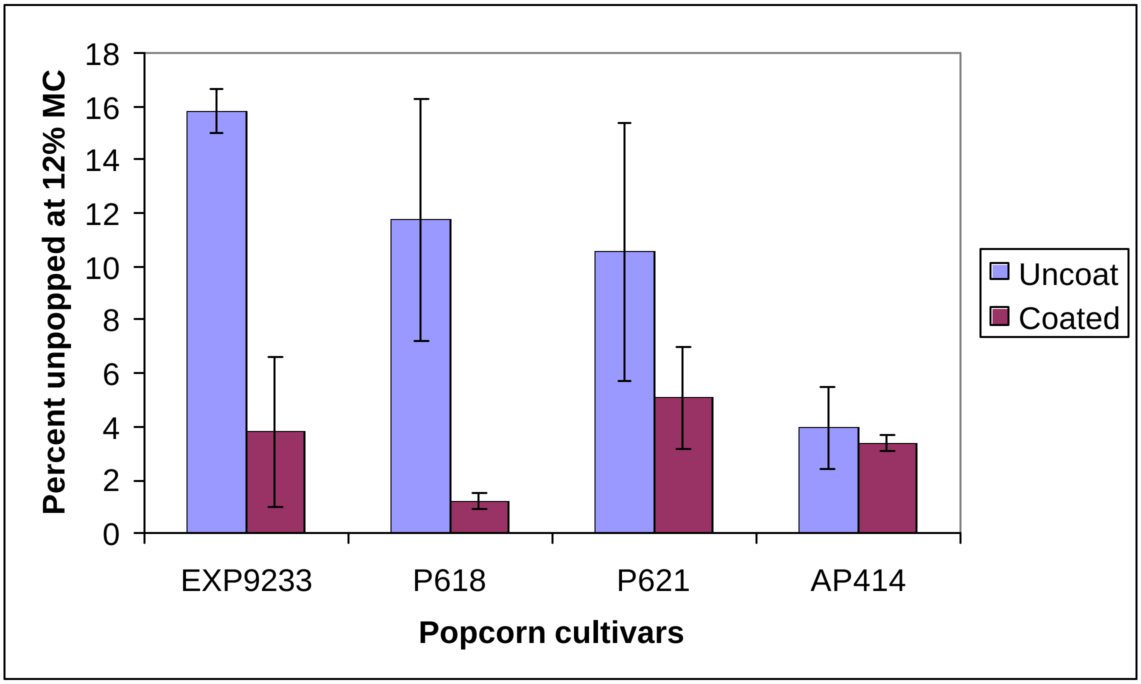

Figure 11. The percent of unpopped kernels of both coated and uncoated popcorn genotypes at 12% moisture content

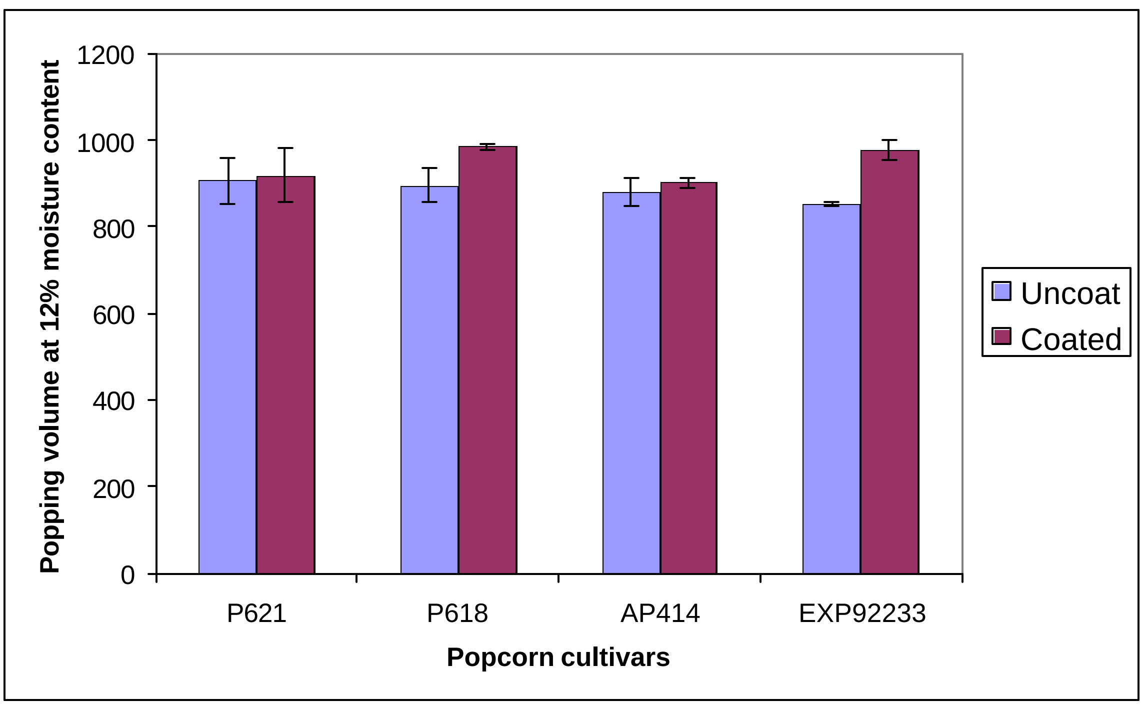

Figure 12. The popping volume of both coated and uncoated popcorn genotypes at 12% moisture content.

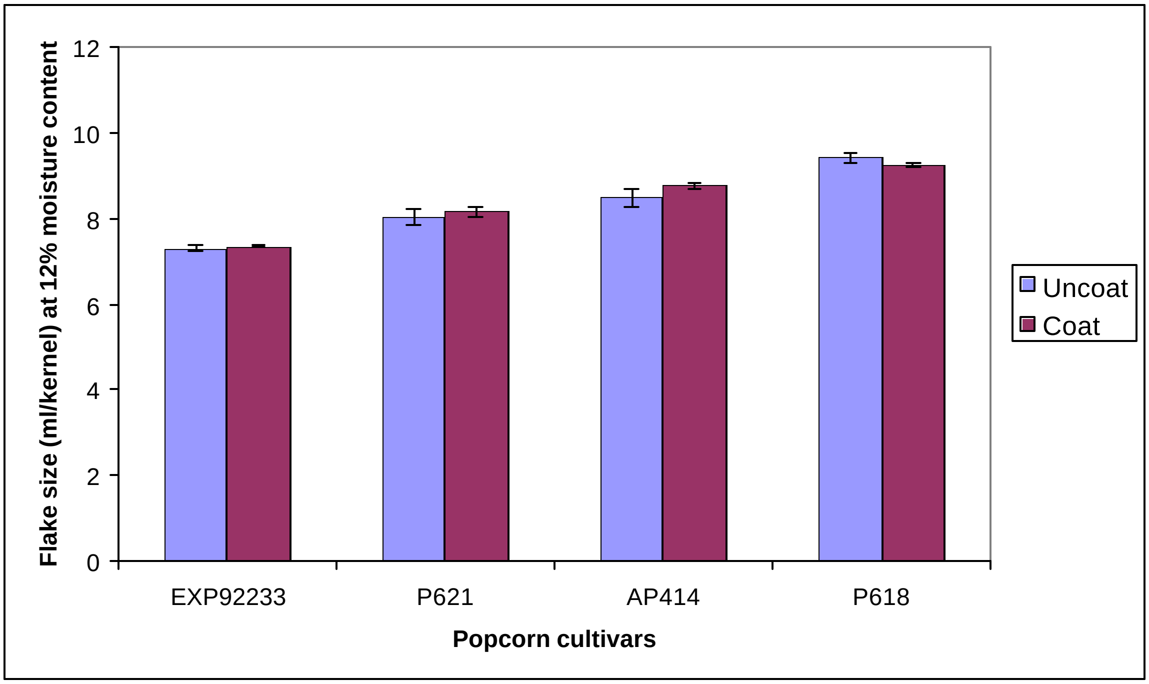

Figure 13. The flake size of both coated and uncoated popcorn genotypes at 12% moisture content.

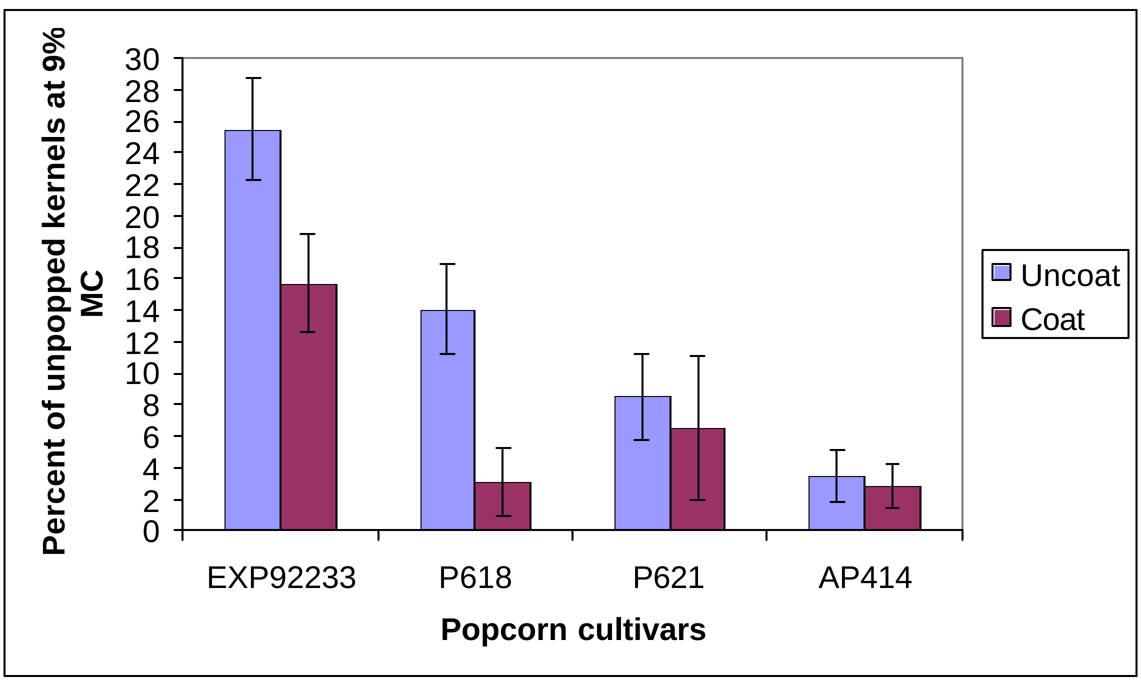

Figure 14. The percent of unpopped kernels of both coated and uncoated popcorn genotypes at 9% moisture content.

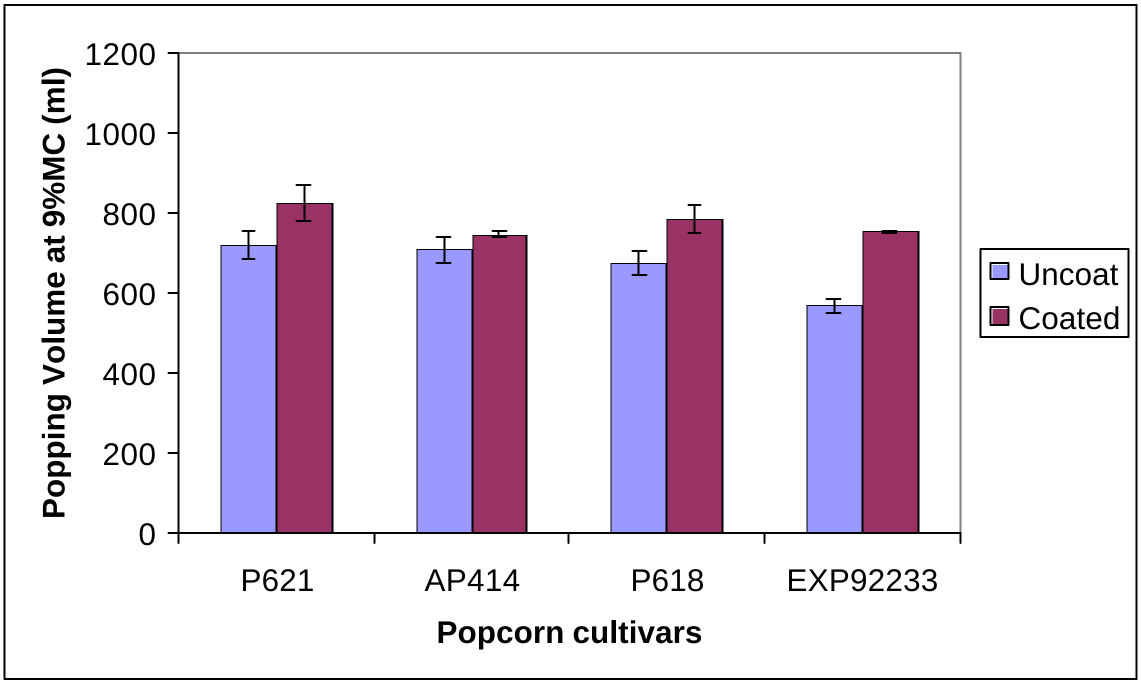

Figure 15. The popping volume of both coated and uncoated popcorn genotypes at 9% moisture content.

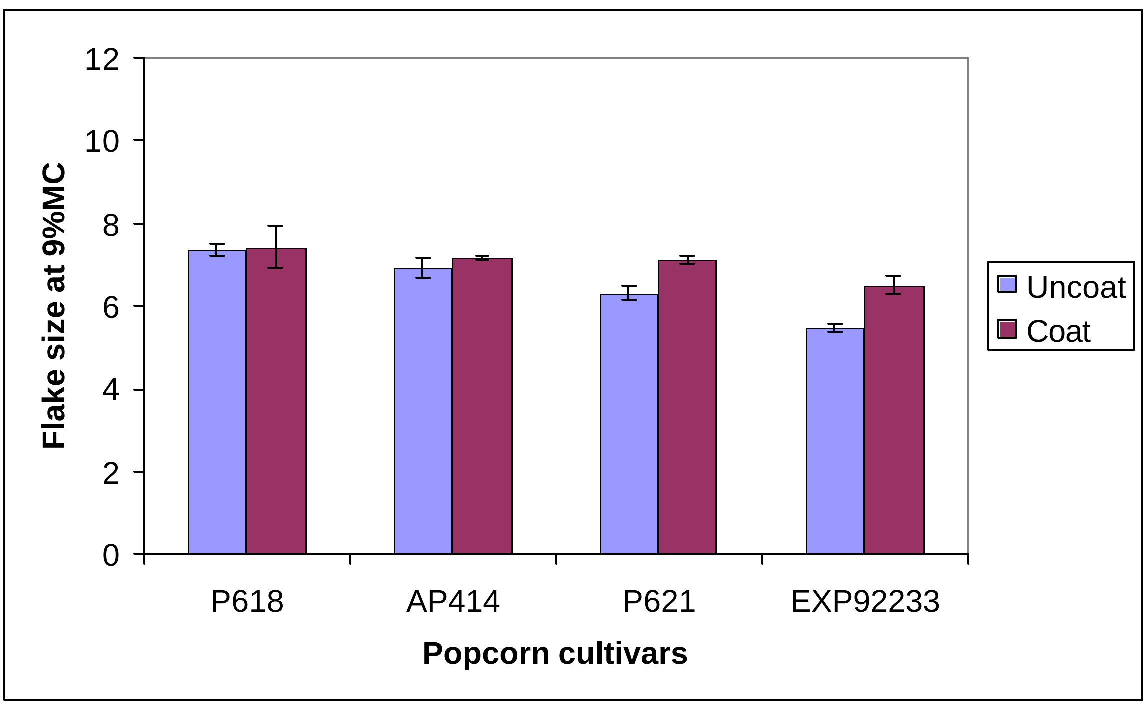

Figure 16. The flake size of both coated and uncoated popcorn genotypes at 9% moisture content.

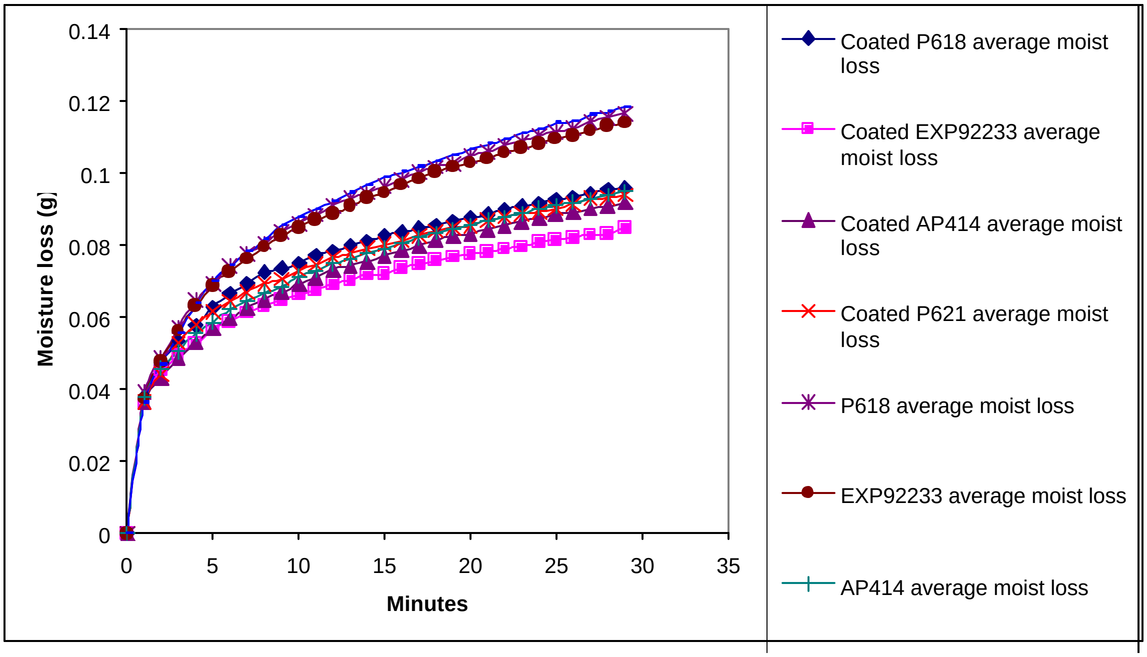

Figure 17. The moisture loss of both coated and uncoated popcorn genotypes during microwave heating.

Popcorn hybrids	Molecular weight (average)
AP414	2.60×10^8
EXP92233	4.17×10^8
P621	5.46×10^8
P618	6.16×10^8

Table 1. Amylopectin molecular weight (Dalton) of different popcorn hybrids as determined using size exclusion chromatography – refractive index - multi angle laser light scattering (SEC-RI-MALLS)